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(54) **Method and arrangement for fluidborne vehicle propulsion and drag reduction**

(57) A body having a propulsion system comprising an inlet (7, 29, 46) and means (6, 28, 43, 45) for drawing fluid through said inlet to be used to propel said body characterised in that said inlet (7, 29, 46) is disposed along a substantial portion of the area of said body where boundary layer separation would otherwise occur at a predetermined speed.

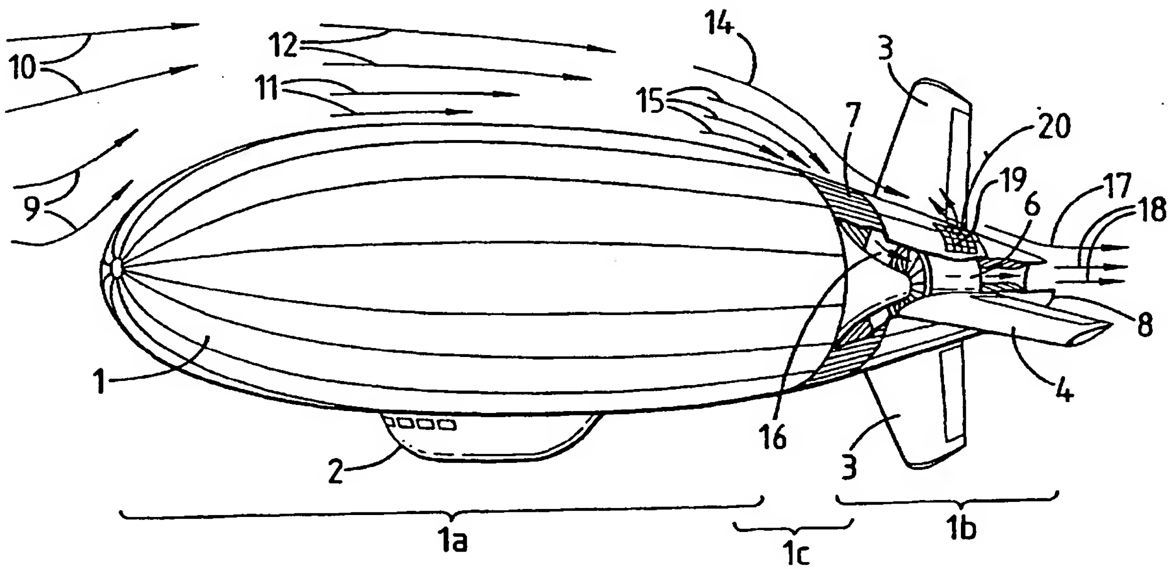

FIG. 1

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Description

This invention relates to a body having a propulsion system comprising an inlet and means for drawing fluid through said inlet to be used to propel said body.

Many types of vehicles use propulsion systems which generate thrust on the vehicle by accelerating surrounding fluid. However, most of these propulsion systems are arranged such that fluid from the free-stream surrounding the vehicle approaches the inlet at or near to the speed of the vehicle relative to the far field fluid medium. For most types of gas turbine powered fixed wing aircraft, this is desirable since the high velocity of the fluid approaching the inlet is transformed into pressure head as the fluid is brought to near stagnation at the engine inlet. This reduces the pressure ratio that must be produced by the gas turbine compressor, which translates into a smaller compressor, higher cycle efficiency for the engine and reduced engine weight. The trade-off of course, is increased form, or pressure, drag of the vehicle as a whole, caused by suspending the blunt engine inlet into the free-stream surrounding the vehicle. This almost universal engine arrangement is likely the result of careful trade-off studies performed in concert by aircraft and engine manufacturers to optimize overall performance of the aircraft; or may simply be a carry-over from reciprocating engine arrangements which do not require large volumes of compressed gas, but are conveniently arranged to drive a propeller rotating in a plane perpendicular to the direction of vehicle motion.

It is also preferable to arrange shaft driven propellers and fans such that the approaching fluid has as near to uniform velocity as possible over the entire inlet area. The propeller and fan blade pitch and geometries can be optimized for a narrow range of approach velocities and individual blades will undergo greater cyclic loading, and hence accelerated fatigue and reduced propulsive efficiency, if the fluid velocity upstream of the propeller or fan has a non-uniform angular distribution. This is another possible motivation for the placing of aircraft propellers and fans out away from the boundary layers generated around lifting surfaces, control surfaces and fuselages.

A number of experimental and commercial aircraft have implemented various departures from the forward facing propeller/fan/engine inlet suspended into the freestream. Rotary-wing aircraft for instance, commonly use radially oriented engine inlets, although the main rotor system and tail rotor are almost always located as far away from the main fuselage as practical and as such do not make use of boundary layer flow. So called "pusher-prop" aircraft use propellers or fans at the rear of one or more fuselage or sponson structures, drawing fluid from the boundary layer surrounding the fuselage or sponson to some extent, but the main portion of the fluid acted on by such propellers is generally accepted to be free-stream flow. Any benefit of removing boundary layer flow in these configurations is negated by the propeller wake i.e., "prop wash" which is larger in diameter than the wake from the fuselage or sponson alone and by the fact that the contribution to overall form drag from the fuselage or sponson boundary layer is small when compared with that generated by the large lifting surfaces.

Experimental aircraft such as the X-21A constructed and tested by the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) have used a sophisticated arrangement of fans, ducts and vent holes distributed over the entire outer surface of the aircraft to almost completely remove all boundary layer fluid. Although the aircraft proved successful from an aerodynamic standpoint, reducing form drag by 20-30%, the complex ducting and exhauster fans left no weight margin for any effective payload and the thousands of small vent holes were impractical from a maintenance standpoint. The holes became almost completely blocked after only a few test flights even in relatively clean runway conditions.

Many other types of fluidborne vehicles use propulsion systems that accelerate fluid surrounding the vehicle but use inlets which face directly forward, drawing fluid only partially from the boundary layer generated by the main body of the vehicle or not at all. Vehicles such as airships have no lifting surfaces and relatively small control surfaces. As such, the form drag of an air ship is due almost entirely to momentum losses in the wake generated by the fluid boundary layer which forms around the main body of the vehicle. Small unmanned aircraft also typically have almost non-existent lifting surfaces and as such, could benefit in terms of reduced form drag if the conventional forward facing engine inlet cowling were replaced with a more conformal engine inlet designed to remove as much fluid as possible from the boundary layer formed around the aft portion of the aircraft's fuselage.

Seagoing vessels have recently begun using water jets in larger numbers which have inlets that are directed more towards the sides of the hull rather than the conventional propeller drawing fluid from what is typically a complex, swirling mixture of boundary layer fluid moving along the bottom of the hull and fluid from the surrounding free-stream. However, conventional water jet propulsion systems currently available for seagoing vessels have small inlets capable of removing boundary layer fluid from only a small portion of the vessel's girth below the waterline. Hence, the majority of the boundary layer flow continues aft only to be released into the turbulent wake behind the ship, where the kinetic energy added to this fluid when it was accelerated nearly to the vessel's forward speed is gradually dissipated in swirling eddies.

Small submersible vehicles, both manned and unmanned have been developed which use propulsion means with a large degree of boundary layer ingestion, but are accompanied by after body shapes that taper

rapidly causing flow separation during under-thrusted, i.e., under deceleration conditions. This flow separation is tolerable for vehicles which have control surfaces in the free stream or forward of the inlet to the propulsion means which can maintain stable attitude control over the vehicle during under-thrusted conditions. However, the preferred location for such control surfaces is in the aftmost section of the vehicle where the greatest control can be applied with the smallest control surface.

Accordingly, there is provided a body having a propulsion system comprising an inlet and means for drawing fluid through said inlet to be used to propel said body characterised in that said inlet is disposed along a substantial portion of the area of said body where boundary layer separation would otherwise occur at a predetermined speed.

Other features of the invention are set out in Claims 2 to 10.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings, in which:

Fig. 1 is a perspective view of an airship arrangement in accordance with the invention;
Fig. 2 is a perspective view of an unmanned aircraft in accordance with the invention; and
Fig. 3a, 3b and 3c are side views of a prior art surface vessel with a propeller propulsion system, a prior art sea going vessel with a nozzle discharge arrangement, and a sea going vessel in accordance with the invention, respectively.

Referring to Fig. 1, a typical airship in accordance with the invention has a main fuselage structure 1 having a forebody section la which includes the largest diameter part of the vehicle, an afterbody section 1b and a transition region lc joining the forebody and afterbody sections. The airship also includes a cockpit and passenger compartment 2, vertical control surfaces 3 and horizontal stabilizers 4. The airship is held aloft by buoyant forces acting on low density gases eg., helium, hydrogen, etc trapped in bags within the main fuselage 1, and as such, requires no lifting surfaces as with heavier-than-air vehicles. Conventional propulsion systems for such airships, typically consist of two or more engine nacelles suspended out from both sides of the cockpit/passenger compartment or the main fuselage. These engines may drive conventional open air propellers or shrouded fans and may be reciprocating engines or gas turbines. Even electric motors powered by a number of sources including batteries and solar cells have been used. The engine inlet typically faces directly forward in the direction of vehicle motion and well away from the cockpit/passenger compartment and the main fuselage to avoid distortion of the inlet velocity profile by the main fuselage boundary layer.

In contrast, in the representative propulsion system arrangement in accordance with the invention, the engine 6 is located within the afterbody section of the fuselage. Preferably the outer surface of the afterbody is tapered inwardly at an angle of no more than 15 degrees from the widest portion of the fuselage main body. Limiting the taper angle of the afterbody in this manner avoids flow separation which can occur under certain propelled conditions, e.g., when the main engine is powered down rapidly while the vehicle is still moving forward at high velocity under its own momentum. Such flow separation over the afterbody can cause loss of control surface effectiveness and loss of vehicle control and stability.

If the vehicle has control surfaces such as the surfaces 3 and 4, the taper angle of the afterbody section should be no more than about 15° in the portion between the transition region lc and the control surfaces. The use of a tapered afterbody in accordance with the invention is particularly beneficial for vehicles having control surfaces which extend beyond the beam of the ship and into the boundary layer. Even if the vehicle has no control surfaces a gradually tapered afterbody will reduce power consumption and maximize the efficiency of the vehicle.

The inlet 7 for the engine 6 circumscribes the main fuselage at the transition region lc near the longitudinal location where the outer surface of the fuselage first begins the taper. Air inducted through the inlet 7 by the engine 6 is discharged out through a converging nozzle 8 that accelerates the fluid thereby generating thrust. The outlet nozzle 8 may be pivotable on one or more axes to direct the thrust angularly with respect to the axis of the vehicle and thereby facilitate steering of the vehicle. In addition, the nozzle 8 may include one or more movable flow guides which may be positioned to reverse the thrust from the nozzle to reverse the direction of the vehicle. Alternatively, the nozzle 8 may include a blocking element to block the flow of fluid and one or more lateral outlet ports may be provided to redirect the fluid laterally or in the forward direction for reverse thrust. The inlet 7 as shown in Fig. 1, incorporates a protective louver to prevent foreign objects e.g., birds, flying debris, etc. above a safe size from being ingested by the engine 6.

The engine 6 may be a conventional turbofan engine as is often used on commercial airliners, or may be a large fan or series of impellers driven by reciprocating engines or electric motors. The engines which drive the fan or impellers may be located forward or aft of the fan/impellers or around the periphery of the fan/impellers and may be partially or totally integrated with the hub or rim that structurally connect the blades of the fan/impellers together. The fan/impellers may have stationary inlet guide vanes and/or discharge guide vanes which may provide structural support for the fan/impellers shaft and bearings. These guide vanes and/or the blades of the fan/impeller may also incorporate variable pitch mechanisms common to many aircraft turbofan engines. The added weight of the engine at the aft por-

tion of the fuselage may be compensated for by moving the cockpit/passenger compartment 2 further forward or moving internal solid ballast within the main fuselage 1 further forward. Additionally, the volume bounded by the outer surface of the afterbody and the inner surface of the flowpath passing through the afterbody provides space for additional gas ballast which can also support some of the vehicle afterbody and engine weight. Optionally, the vehicle may include any number of appendages aside from the cockpit/passenger compartment 2 or the control surfaces 3, 4 which project out into the fluid surrounding the vehicle to provide space for vehicle components which are more readily accommodated outside the bounds of the forebody and afterbody sections of the vehicle.

The aerodynamic benefits of the propulsion system shown in Fig. 1 are threefold. First, the boundary layer 11 formed around the main body of the vehicle, which for an airship and many other similar fluidborne vehicle configurations constitutes most of the viscous boundary layer formed around the vehicle, is substantially reduced by placing the engine inlet 7 in the transition region of the vehicle. The inlet 7 draws in a substantial portion of the boundary layer fluid 15 just before it would normally begin to shed off from the tapering aft section into the wake behind the vehicle where the energy expended by accelerating the fluid to near the vehicle's forward speed through the fluid medium would normally be unproductively dissipated. The boundary layer 11 forms when near stagnant fluid 9 ahead of the vehicle is displaced as the vehicle approaches and due to viscous shear stress, becomes drawn along with the surface of the vehicle. Fluid 12 further away from the path of the vehicle 10 is less affected. Further downstream, the fluid 11 near the surface of the vehicle becomes further entrained in the growing viscous boundary layer, while the fluid further away from the surface 12 remains relatively unaffected.

As the fluid entrained by the boundary layer approaches the inlet 7, the fluid 15 is drawn into the intake and the fluid 14 from the distal free-stream fills in behind the inlet 7, leaving only a relatively thin boundary layer. The fluid drawn in through the inlet 7 continues on through the propulsion system as shown at 16. The thin remaining boundary layer 17 is shed over the propulsion nozzle 8 and mixes with the propulsion system discharge 18 which leaves the vehicle at only a moderately higher velocity. This results in a wake of disturbed air behind the vehicle having a diameter only slightly larger than the nozzle discharge 8. In contrast, the wake created by the boundary layer shed by a conventionally designed vehicle would be equal to or greater than diameter of the main body of the vehicle at its mid section. The smaller wake corresponds to much less energy being dissipated into the fluid medium surrounding the vehicle.

The second advantage to the propulsion system arrangement shown in Fig. 1 is that the component of fluid velocity at the inlet 7 is small, particularly in the direction of vehicle motion, as compared with a conventional forward facing nacelle mounted propulsion system. Thrust is generated by each type of propulsion system by accelerating fluid from the vehicle's surroundings. The direction in which the fluid is accelerated must be directly opposite from the direction in which thrust is desired. The magnitude of the thrust can be expressed in terms of the inlet velocity, $\underline{V}_{in}$, the discharge velocity, $\underline{V}_{out}$ and the mass flow rate of fluid through the propulsion system, m, as follows:

$$\text{Thrust}=m(\underline{V}_{in}-\underline{V}_{out})$$

where the underscore for $\underline{V}_{in}$ and $\underline{V}_{out}$ indicates that these are vector quantities. Therefore, for a given mass flow rate of fluid, the thrust is proportional to the difference in the vector components of inlet and discharge parallel to the direction in which thrust is generated.

For a conventional propulsion system, the inlet velocity is nearly equal to the free-stream velocity. Therefore, the fluid discharged from the nacelle must be accelerated to speeds substantially greater than the free-stream velocity, resulting in a severely disturbed wake behind the propulsion systems and the associated energy dissipation. In the propulsion system arrangement according to the invention, the fluid entering the inlet 7 has a velocity close to that of the vehicle and as such, need only be accelerated to at or above, i.e., O to 60% above, the free-stream velocity of the fluid passing over the vehicle. The required velocity differential between the discharge 18 and the surrounding fluid 17 is much less, resulting in reduced energy dissipation in the jet produced by the propulsion system. The component of fluid velocity at the inlet 7 is further reduced by the large size of the inlet as compared to a conventional system, and by inducting the surrounding fluid in a more radially inward direction rather than directly axially as is unavoidable with the conventional system.

The axial component of the fluid crossing the structural boundary of the vehicle at the inlet 7 will be equal to the magnitude of the fluid particle velocity multiplied by the cosine of the angle that the path of the fluid particle makes with the central axis of the vehicle. Therefore, it is desirable to maximise the inlet area, place it where the boundary layer fluid velocity is as close to the vehicle velocity as possible i.e., as far aft as possible but before the boundary layer begins the thicken substantially along the afterbody, and arrange flow guides and/or structural members in the inlet 7 to promote radially inward flow to the maximum extent possible without causing local flow separation around the flow guides.

A third advantage of the propulsion system shown in Fig. 1 is that it produces thrust that is coaxial with the center of drag of the vehicle and can be made to have no net reaction torque on the vehicle. In conventional

propulsion systems, it is desirable to place the nacelles low on the vehicle for accessibility. However, this causes a reaction torque that tends to drive the nose of the vehicle upward due to the difference between the axis along which the drag force on the vehicle acts and the axes along which thrust is applied. This is typically corrected for by setting the horizontal stabilizer at an angle which counteracts this reaction torque. However this increases the wake of disturbed air generated by this control surface, which results in greater losses.

Another problem common to conventional propulsion systems is that it is desirable from a cost standpoint to have the nacelle assemblies, including the engines inside, be identical with the exception of the attachment point. This means that the direction of rotation for each engine will be the same, thereby creating torque on the vehicle tending to make it roll. Counter-rotating engines can be used in each nacelle, but this generally dictates two distinct engine designs, which is generally cost prohibitive and does not reduce rolling torque for single engine operation. The rolling torque can be corrected for by skewing the vertical or horizontal control surfaces at slight differential angles, but again, the wake of disturbed fluid generated behind the control surfaces is increased.

In contrast, the single propulsion unit 6 may have one or more pairs of counter-rotating fan/impellers or stationary flow straightening guide vanes such that the net reaction torque created by the driving engine(s) is zero, thereby avoiding any skewing of the control surfaces and the associated drag increase and eliminating rotational wakes produced by the propulsion unit discharge.

This configuration of the propulsion unit 6 results in a further improvement in propulsive efficiency of the vehicle since rotational components of fluid velocity in the wake generated by the discharge 18 are substantially reduced by the use of counterrotating fan/impellers or flow straightening stationary guide vanes.

The propulsion system shown in Fig. 1 also permits incorporation of several additional attitude control and manoeuvring features. One such feature, that is sometimes incorporated with conventional propulsion systems, is thrust vector control. In conventional systems, this is accomplished by rotating the nacelle, or a portion of its discharge, in the vertical or horizontal plane so that thrust is directed at some angle to the central axis of the vehicle, resulting in a reaction torque that causes the heading of the vehicle to change. The same type of directional control may be obtained by mounting the nozzle 8 so that it can be articulated in the horizontal and/or vertical planes, diverting the fluid being discharged 18 at some angle to the central axis of the vehicle.

Another manoeuvring feature that may be incorporated in the propulsion system according to the invention is thrust reversing. This is accomplished by providing a set of doors or other movable feature downstream of the engine but upstream of the discharge that can be shifted so as to block discharge of fluid out of the nozzle 8 and divert this fluid out of openings 19 on the sides 20 of the rear section of the vehicle that causes the discharged fluid to be directed forward. This causes a reverse thrust that can be used for backing the vehicle or for stopping or slowing forward motion of the vehicle.

The propulsion system arrangement shown in Fig. 1 can also be adapted to winged aircraft, although the hydrodynamic benefits as discussed herein are not as great if the vehicle uses large lifting surfaces to remain fluidborne. However, for small high speed vehicles which typically have small lifting and control surfaces as shown in Fig. 2, this type of propulsion system arrangement can provide substantially increased range and performance.

The vehicle shown in Fig. 2 includes a main body 21 having a forebody section 21a which includes the largest diameter portion of the vehicle, an afterbody section 21b and a transition region 21c. The vehicle also includes small lifting surfaces 22, 23, vertical and horizontal control surfaces 24, 25, 26, 27 and a propulsion system including a turbofan engine 28 or other axial type fluid moving device. In accordance with the invention, the afterbody section 21b is tapered at an angle of no more than about 15° with respect to the direction of motion and the transition region 21c includes an inlet 29 through which the propulsion system inducts fluid from the boundary layer 30 flowing along the main body 21, and discharges this fluid 31 through a nozzle 32. The advantages described above for the airship shown in Fig. 1 are essentially applicable to this vehicle.

A typical prior art engine inlet for this type of vehicle is located underneath the vehicle and includes a cowling with a forward facing opening. This type of inlet is suitable if the typical engine used to drive the turbofan is an air-breathing, hydrocarbon-burning gas turbine that requires air coming in the intake to be compressed. The cowling will act to supercharge the inlet thereby reducing the size consumption by the compressor. However, small unmanned aircraft will sometimes use more exotic, one-time use drive means for the turbofan such as lithium metal reacting with water to generate steam that is used to drive a steam turbine which in turn drives the turbofan. This type of drive is not air-breathing so supercharging the inlet serves no purpose and, as such, is well suited for use in vehicles in accordance with the invention.

The propulsion system arrangement in accordance with the invention may also be used for propulsion and drag reduction of sea going surface craft. A conventional sea going craft shown in Fig. 3a includes a vessel 34 with a waterline 35 and a rudder 37 aft of an open propeller 36. The propeller 36 is driven by a lineshaft 38 which in turn is typically driven by reduction gear 39 and main engine 40. The velocity of the fluid approaching the open propeller 36 is non-uniform due to the boundary layer which forms around the vessel's hull. The fluid velocity near the hull where the upper propeller blades

are positioned like hands between 10:00 to 2:00 on a clock face is very low relative to the vessel, while the fluid away from the hull where the lower propeller blades are acting i.e., the 6:00 position, is high relative to the vessel, nearly equal to the free-stream velocity of the hull. Because rotating blade rows can be designed to operate efficiently for one given velocity approaching fluid, the blades in an open propeller arrangement are typically only operating near optimum conditions as they rotate through the 3:00 and 9:00 positions. Through the remainder of their rotation, the blades operate in an "off-design" condition which can result in a loss of efficiency of up to 50% at some angular positions. Open propellers also can typically only ingest a small portion of the boundary layer created by the hull upstream of the propeller. This results in substantial residual form drag due to the viscous wake left by the vessel that could be avoided if better boundary layer management is used.

The waterjet configuration shown in Figure 3b is also a commonly used surface craft propulsion arrangement which provides thrust by ejecting a jet of fluid from the nozzle 41. The fluid is inducted through an inlet opening 42 by a pump unit 43 which is driven by a motor 45 and is then discharged through the nozzle 41. The inlet velocity profile entering to the rotating blade row within the pump unit 43 can be corrected to approach a uniform angular distribution by careful shaping of the inlet opening 42 and a bend 44 in the inlet passage or by introducing stationary inlet guide vanes, which provide for near constant efficiency of the rotating blades at all angular positions. This improvement in efficiency generally compensates for the additional losses introduced by the internal ducting associated with the waterjet configuration that is not present in an open propeller arrangement, resulting in overall propulsion efficiencies which are comparable e.g., 60-65%. However, as with the open propeller configuration, the conventional waterjet configuration inlet opening is confined to a small portion of the boundary layer formed over the entire surface of the vessel's hull below its waterline. This leaves a large portion of the viscous wake created by the vessel's hull below its waterline. Accordingly, a large portion of the viscous wake created by the vessel is not scavenged by the propulsion system which again results in residual form drag on the vessel that could be avoided to a large extent by improved boundary layer management.

Fig. 3c shows a configuration for a sea going surface vessel in accordance with the invention. As in the airborne vehicles shown in Figs. 1 and 2, the vessel 34 of Fig. 3c includes a forebody section 34a which includes the largest width portion of the vessel, an afterbody section 34b which is tapered at an angle of no more than about 15° and a transition region 34c joining the forebody and afterbody sections. In accordance with the invention, a fluid inlet opening 46 which encompasses substantially all of the girth of the vessel's hull below the waterline is provided in the transition region 34c. This allows the propulsion inlet to effectively scavenge most of the boundary layer fluid attached to the moving hull. Removing this boundary layer fluid reduces wake formed by the vehicle, and as a result, improves pressure recovery aft of the propulsion system inlet, reducing form drag of the vehicle. This should improve the overall propulsive efficiency of the vessel by up to 5% relative to conventional waterjet inlets in most cases.

Although the invention has been described herein with respect to specific embodiments, many modifications and variations therein will readily occur to those skilled in the art. For example, many other types of fluidborne and even some types of landbound vehicles may benefit from the disclosed propulsion system arrangement. Surface-effect craft may implement a similar propulsion system by arranging the inlets for the turbofan engines which provide propulsion and/or air flow to the surface-effect lifting cushion and which are arranged to draw-off the boundary layer at an optimized location on the vehicle over the whole perimeter above the air cushion. Vehicles immersed in water may include a propulsion arrangement similar to the airship shown in Fig. 1, except the propulsion system may use a fluid moving device that is appropriate for liquids e.g., and axial flow pump with one or more co-rotating or counter-rotating mechanically or electrically driven impellers. Accordingly, all such variations and modifications are included within the intended scope of the invention.

Claims

1. A body having a propulsion system comprising an inlet (7, 29, 46) and means (6, 28, 43, 45) for drawing fluid through said inlet to be used to propel said body characterised in that said inlet (7, 29, 46) is disposed along a substantial portion of the area of said body where boundary layer separation would otherwise occur at a predetermined speed.

2. A body having a propulsion system, said body including a forebody section, an afterbody section and a transition region joining the forebody and afterbody sections, the forebody section having an outer surface with a shape diverging from the forward most point of the vehicle to and including the widest portion of the vehicle, the afterbody section having an outer surface with a shape converging inwardly in the rearward direction of the vehicle, at least a portion of the surface of the vehicle contacting a fluid medium,

   an inlet located in the transition region for inducting fluid from the fluid medium, the inlet circumscribing a substantial portion of the surface of the vehicle in contact with the fluid medium, pumping means for inducting the fluid through the inlet and increasing the pressure of the flu-

id, and

a discharge means for receiving the pressurized fluid from the pumping means and discharging the pressurized fluid from the aft end of the vehicle wherein the velocity of the discharged pressurized fluid is greater than the velocity of the fluid inducted into the inlet and fluid flowing over the afterbody section is substantially free of separation both when the vehicle is propelled at constant speed by the pumping means and when the vehicle is coasting following a reduction in pumping by the pumping means.

3. A body as claimed in Claim 1 or 2, wherein the portion of said body aft of said inlet converges rearwardly towards a centre line of the body or to the direction of motion of said body, preferably at an angle of not greater than 15° from the direction of motion.

4. A body as claimed in Claim 1, 2 or 3, wherein the portion of said body aft of said inlet includes appendages (3, 4, 24, 25, 26, 27) for stabilizing said body which appendages may include movable portions (20, 24, 25, 26, 27) which, when activated provide directional control of said body.

5. A body as claimed in any of Claims 1 to 4, wherein said inlet (7, 29, 46) comprises streamlined members which, in use, help direct fluid into said inlet (7, 29, 46) and wherein said streamlined members may be spaced in a manner such as to substantially prevent ingress of foreign objects.

6. A body as claimed in any preceding claim, including discharge means to propel said body which discharge means may include a movable flow guide for providing a reverse thrust and/or directional control of said body.

7. A body as claimed in any preceding claim, wherein the means for drawing fluid through said inlet includes at least one pair of counter-rotating axial flow impellers (43) which may further include an electric motor (45) for driving said impeller; each axial flow impeller may include a rim, impeller blades mounted onto the outer rim, the outer rim connecting the tips of the impeller blades, a motor stator disposed around the periphery of the outer rim, and an armature integral with the outer rim.

8. A body as claimed in any preceding claim, wherein when the vehicle is fully immersed in the fluid medium supporting the vehicle, the weight of the fluid medium displaced by the vehicle equals the weight of the vehicle such that the vehicle can be supported in the fluid medium by buoyant forces such as an airship or submarine.

9. A body as claimed in any of Claims 1 to 7, wherein when the vehicle is fully immersed in the fluid medium supporting the vehicle and the weight of the vehicle is greater than the fluid medium displaced by the vehicle, the vehicle further including horizontal lifting surfaces that provide sufficient upward force to support the weight of the vehicle upon motion of the vehicle through the fluid medium such as an aeroplane.

10. A body as claimed in any of Claims 1 to 7, wherein when the vehicle is partially immersed in the fluid medium supporting the vehicle and the weight of the vehicle is equal to the weight of the fluid displaced by the vehicle such that the vehicle can be supported by buoyant forces such as a boat.

11. A body as claimed in any preceding claim, wherein the body includes at least one appendage (2) which projects out into the fluid to provide space for components and/or passages.

12. A method for propelling a body as claimed in any preceding claim through a fluid, said method comprising the steps of drawing said fluid through an inlet in said body to be used to propel said body, characterised in that said fluid inlet is disposed along a substantial portion of the area of said body where boundary layer separation would otherwise occur at a predetermined speed.

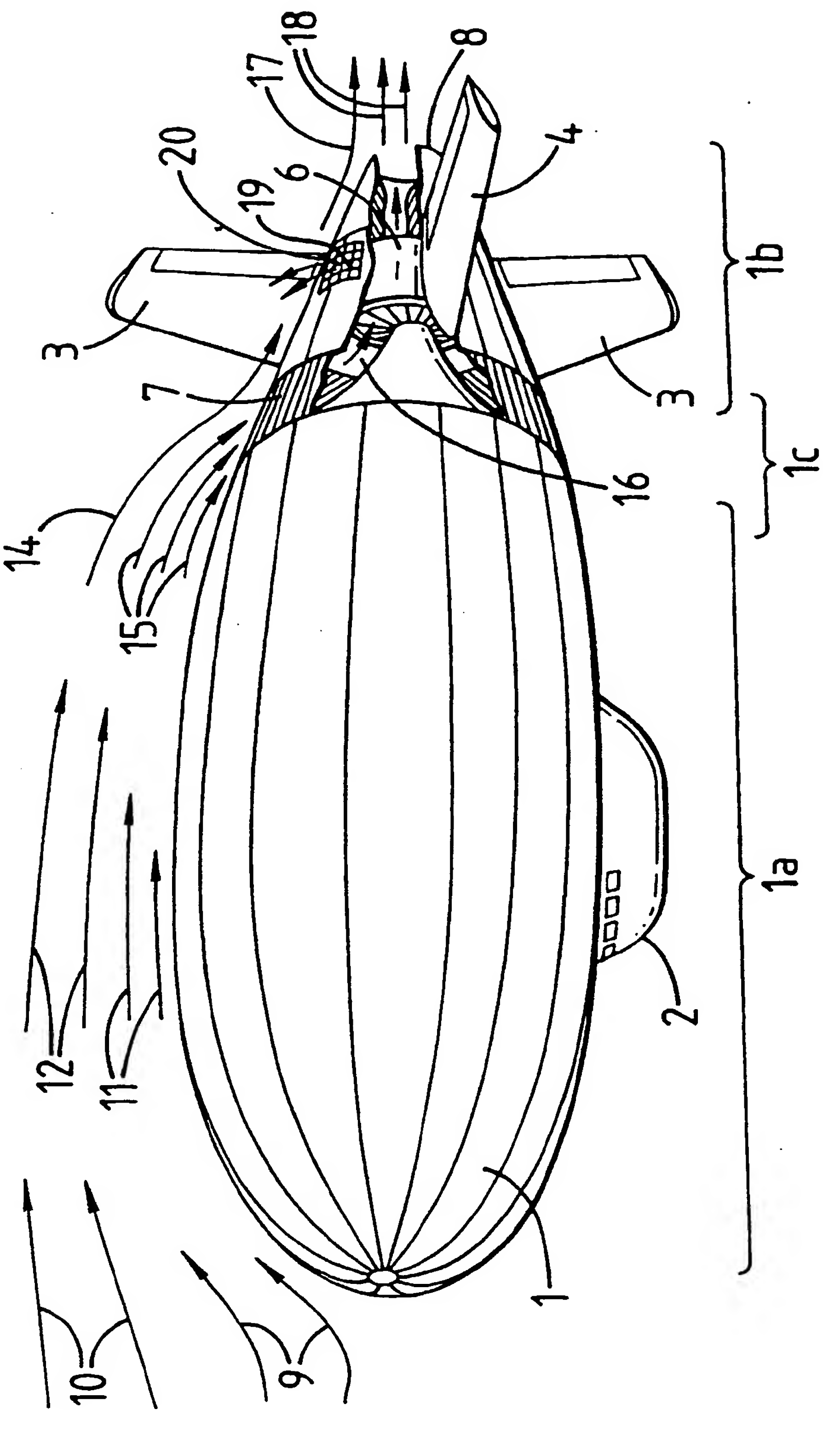

FIG.1

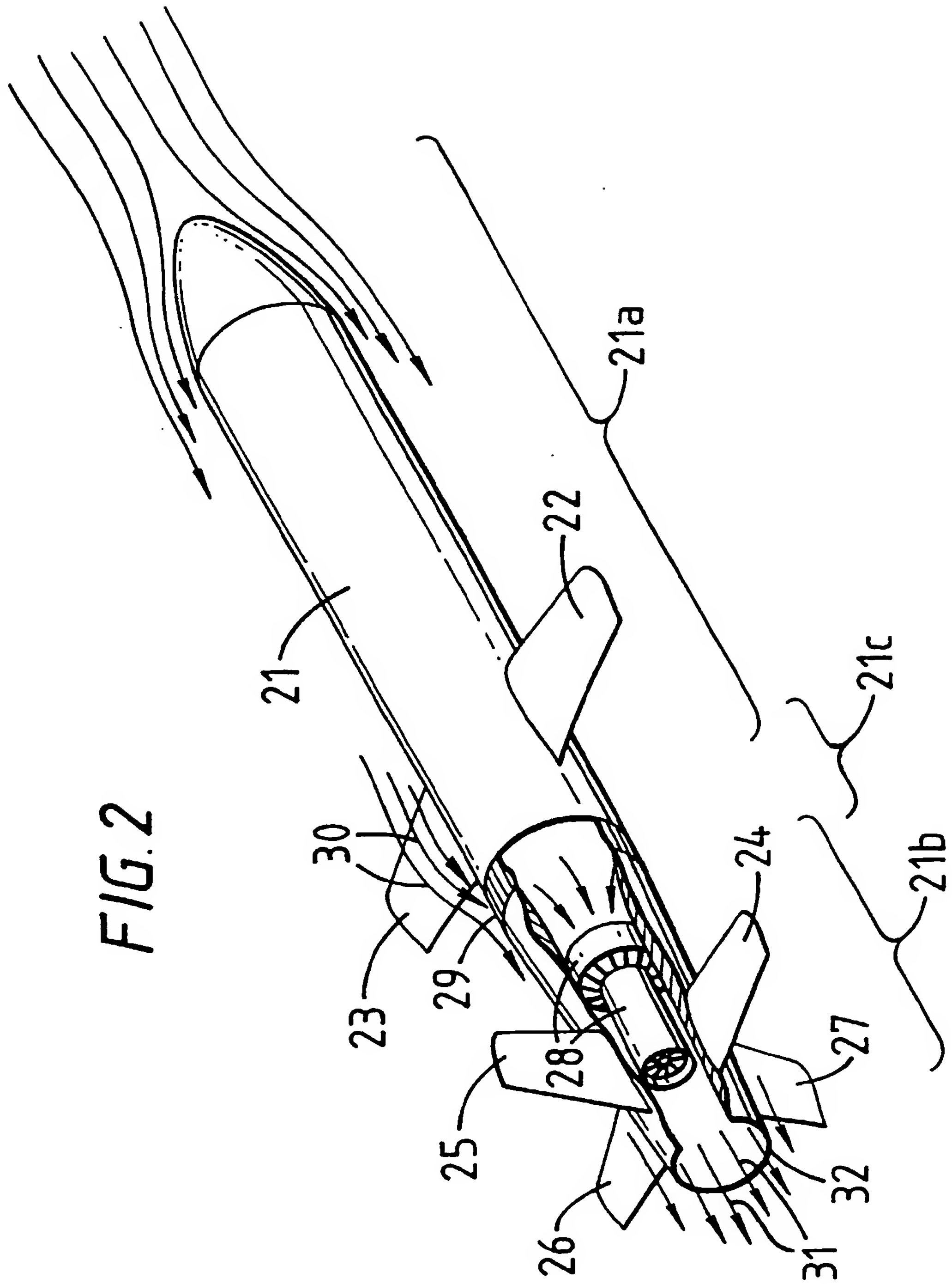

FIG. 2

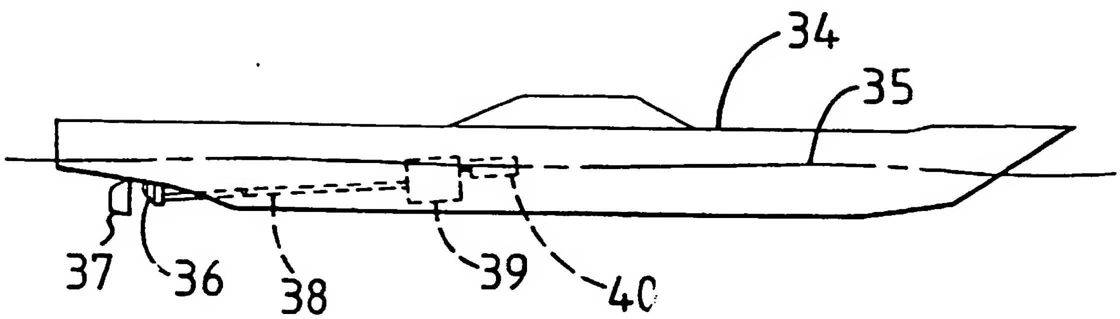

FIG. 3a (PRIOR ART)

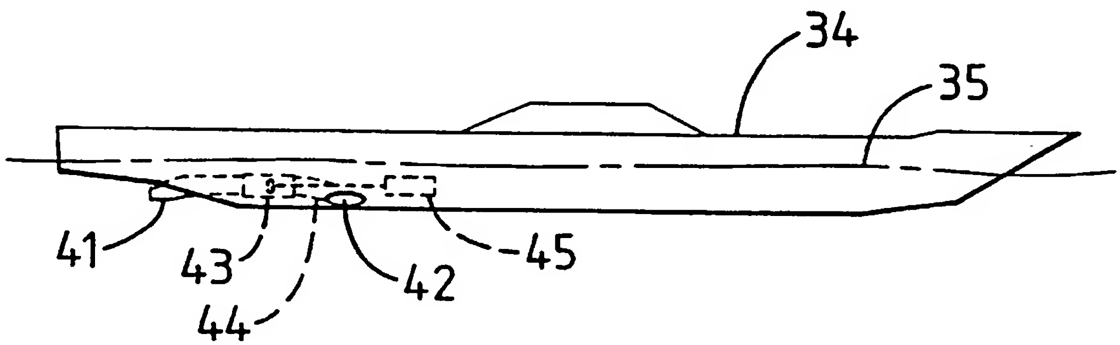

FIG. 3b (PRIOR ART)

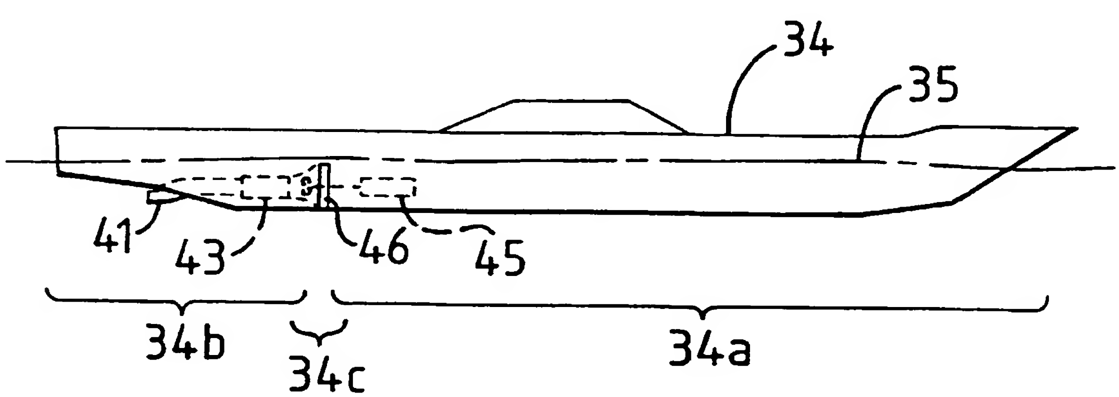

FIG. 3c

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(54) **Method and arrangement for fluidborne vehicle propulsion and drag reduction**

(57) A body having a propulsion system comprising an inlet (7, 29, 46) and means (6, 28, 43, 45) for drawing fluid through said inlet to be used to propel said body characterised in that said inlet (7, 29, 46) is disposed along a substantial portion of the area of said body where boundary layer separation would otherwise occur at a predetermined speed.

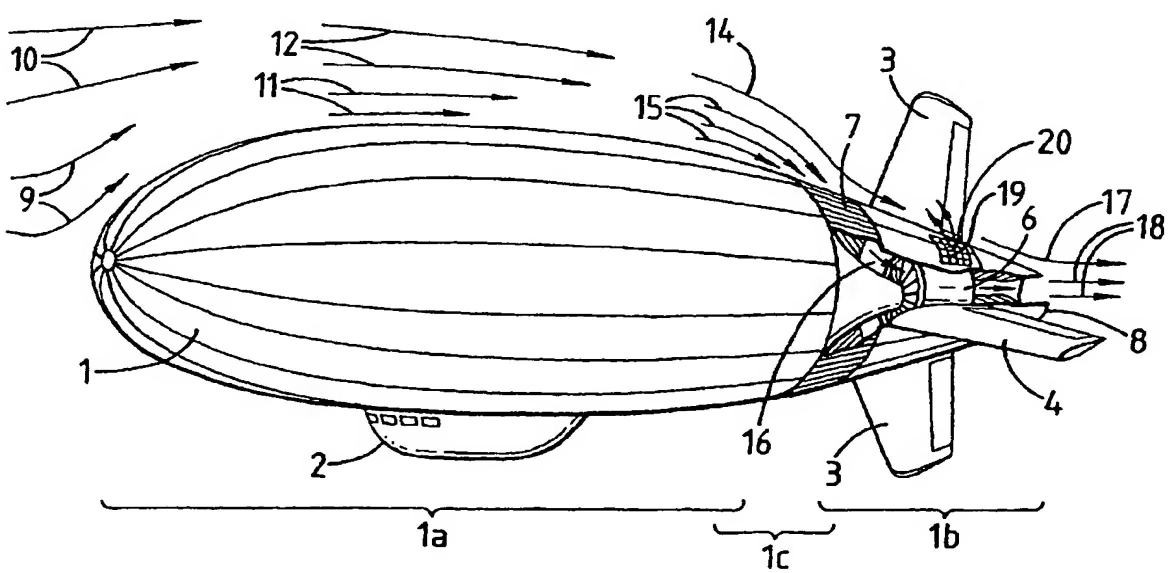

FIG. 1

EP 0 887 259 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 98 20 2072

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	1 November 1999	Estrela y Calpe, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 98 20 2072

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82